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G3R RBE72
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EP 0814249 A

(58) Field of Search
UK CL (Edition R) **G1N NBKT NBMH , G3R RBE72**
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ONLINE: EPODOC, JAPIO, WPI, English language full-text databases

(54) Abstract Title
Exhaust gas cleaning system with trimming of upstream lambda sensor output

(57) In an internal combustion engine 20 with a three-way catalytic converter 22, a certain signal level of the upstream lambda probe 23 is assigned a lambda value λ_0 which is close to 1. In place of a lambda probe downstream of the three- way catalytic converter 22, use is made of an NOx-sensitive sensor 24, in which a connection between NOx concentration in the exhaust gas and lambda value, and an internal signal Ip0 of the sensor 24 has a change of sign at lambda = 1, since the signal of the sensor 24 due to an NH_3 cross sensitivity at lambda = 1 has only a local minimum. The outputs of the NOx sensor are used to correct (trim) the values assigned to λ_0. The NOx sensor has an oxygen sensing cell 4, a NOx sensing cell 8, with the current Ip2 measured at A indicating the NOx concentration.

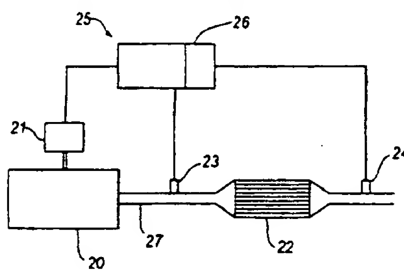

Fig.2

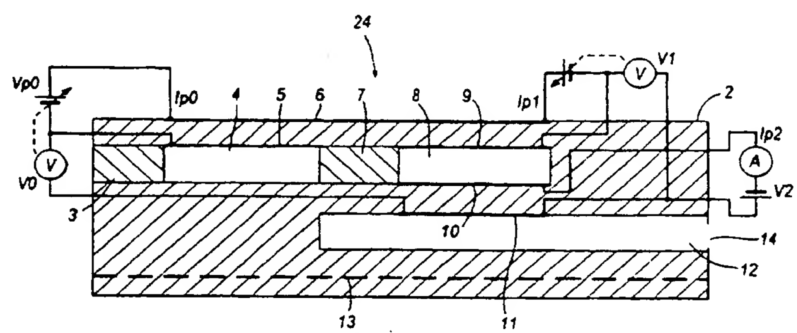

Fig.4

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1995

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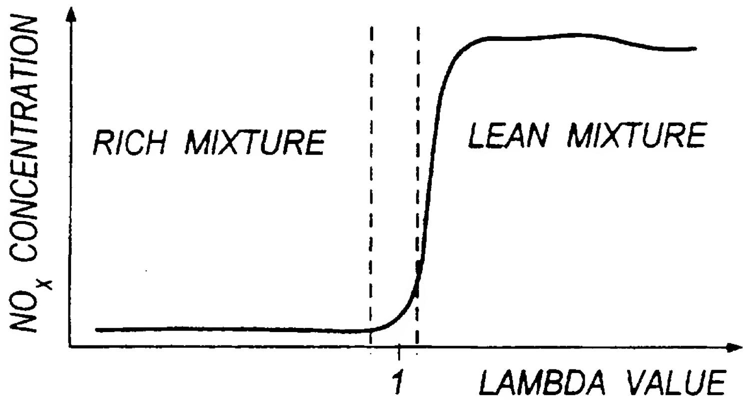
NO_x CONCENTRATION
RICH MIXTURE
LEAN MIXTURE
1
LAMBDA VALUE

Fig.1

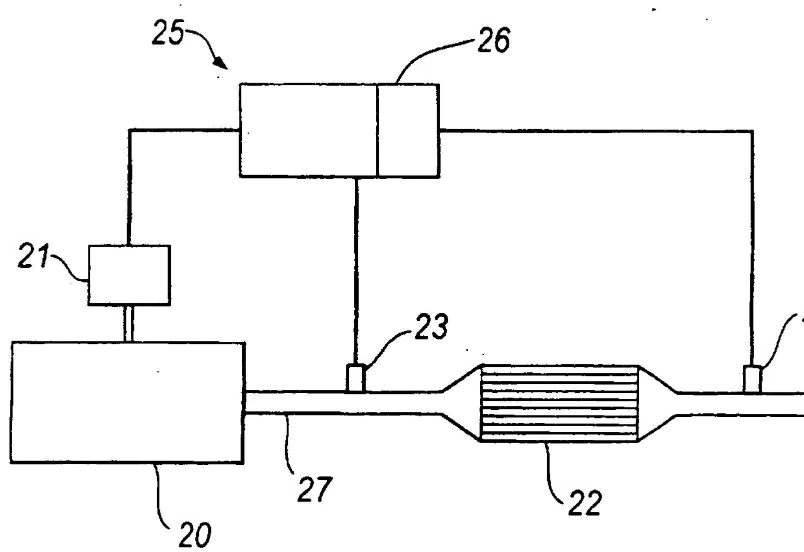
25
26
21
23
24
20
27
22

Fig.2

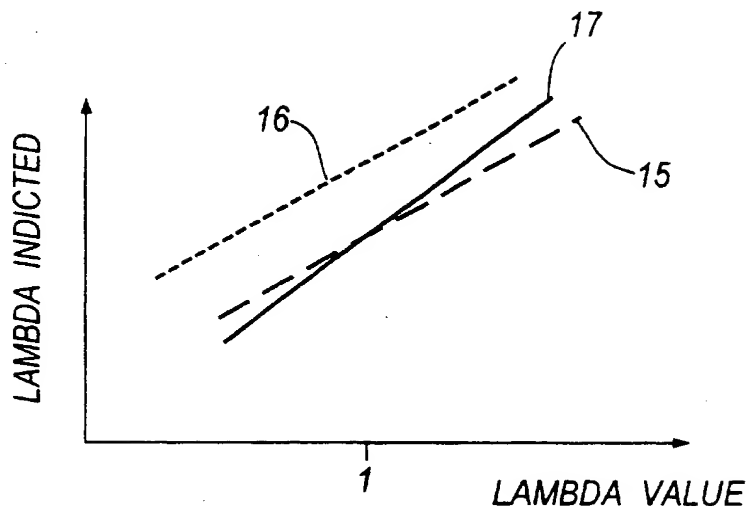
17
16
15
LAMBDA INDICTED
1
LAMBDA VALUE

Fig.3

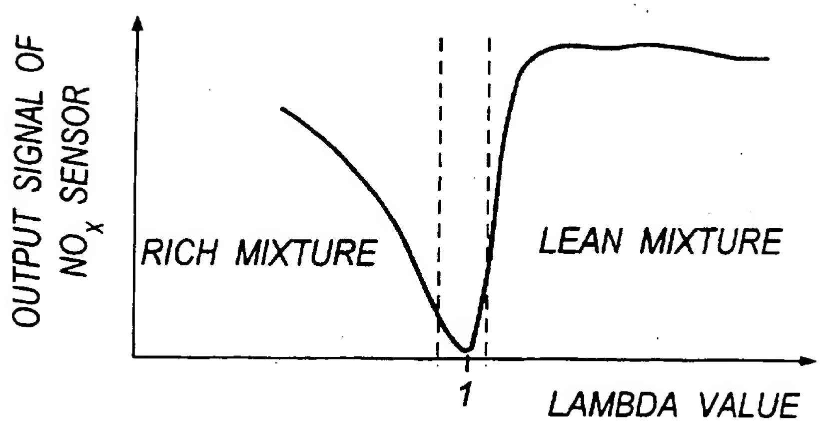
OUTPUT SIGNAL OF
NO_x SENSOR
RICH MIXTURE
LEAN MIXTURE
1
LAMBDA VALUE

Fig.5

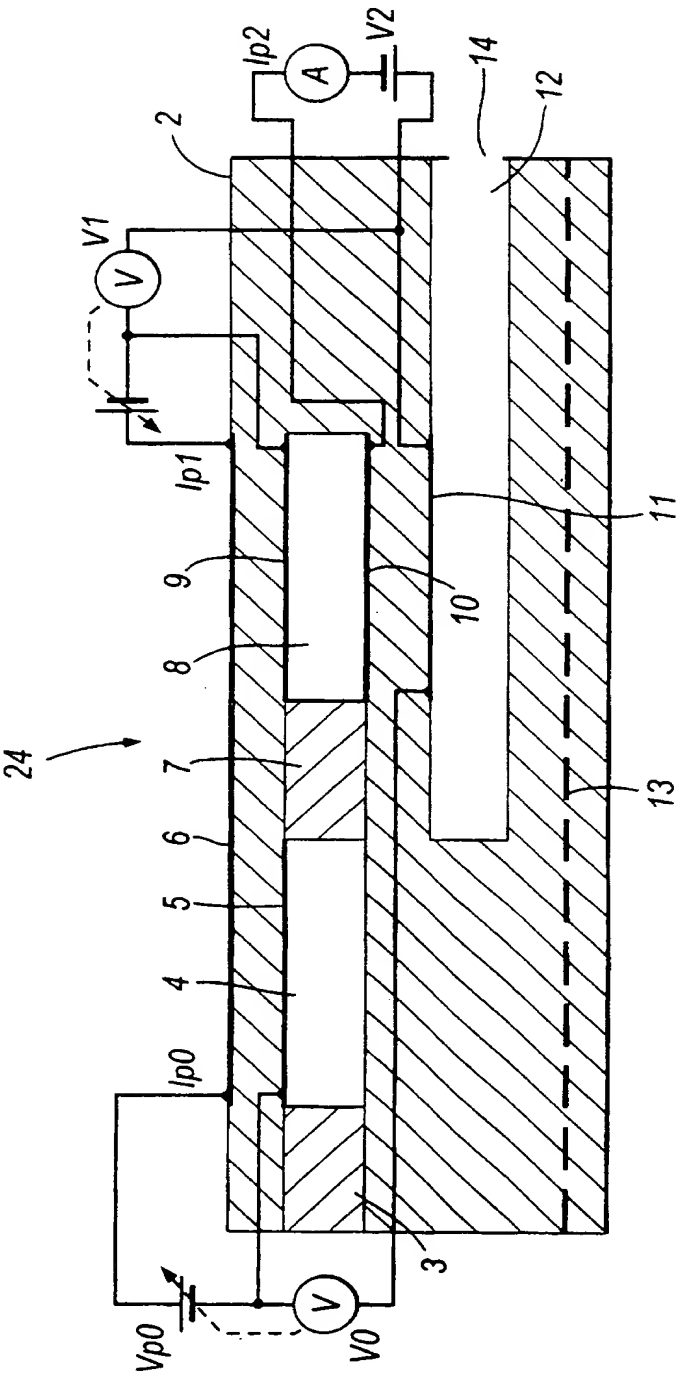

Fig.4

METHOD AND DEVICE FOR CLEANING EXHAUST GAS WITH TRIM REGULATION

This invention relates to a method and a device for cleaning of the exhaust gas of an internal combustion engine according to the pre-characterising clause of claims 1 and 5, respectively.

For cleaning the exhaust gas of an internal combustion engine, a three-way catalytic converter is conventionally arranged in the exhaust gas tract of the internal combustion engine. Upstream of this catalytic converter, a lambda probe is provided, the emitted signal of which is dependent, as in all lambda probes, upon the residual oxygen contained in the exhaust gas. This residual oxygen component in turn depends on the mixture which was introduced into the internal combustion engine. In the case of an excess of fuel (rich mixture), the oxygen component in untreated exhaust gas is lower; in the case of an excess of air (lean mixture), it is higher.

With a lean mixture (lambda > 1), the output voltage of the lambda probe is ordinarily less than 100 mV; in the area of lambda = 1, it changes suddenly, and with a rich mixture (lambda < 1) it becomes greater than 0.8 V. This is referred to as two-point behaviour.

Also known are lambda probes which deliver a distinctive, steadily increasing signal in an additional lambda range (0.7 to 4). These lambda probes are also designated as broadband lambda probes.

In the operation of the internal combustion engine, the output signal of the lambda probe which reflects the lambda value of the untreated exhaust gas fluctuates around a predetermined mean value which may be assigned lambda = 1. Since a three-way catalytic converter has optimal catalytic properties for

untreated exhaust gas with a certain lambda value λo, the predetermined mean value or the value assigned to λo should also correspond to the actual λo. Depending on the catalytic converter, lambda value λo for optimal catalytic effect can deviate slightly from lambda = 1; for example, it can be around lambda = 0.99.

The dynamic and static properties of the lambda probe upstream of the three-way catalytic converter, however, are changed through ageing and poisoning. As a result, the position of the signal level corresponding to λo is shifted. Therefore in the state of the art, downstream of the three-way catalytic converter is positioned an additional lambda probe which is less susceptible to poisoning. It serves as a monitor probe for monitoring the catalytic conversion and facilitates fine control of the mixture in that the signal level of the upstream lambda probe assigned to the value λo is corrected such that the lambda value λo most favourable for the conversion can always be maintained. This method is designated pilot or trim regulation.

To further reduce pollutant emissions of modern internal combustion engines, an NO_x catalytic converter can be provided in addition to the three-way catalytic converter. This NO_x catalytic converter can also be integrated into the three-way catalytic converter. For optimal operation of such a catalytic converter, which by way of example can be a storage catalytic converter which in one operating state of the internal combustion engine stores NO_x and in another operating state converts the stored NO_x, an NO_x-sensitive sensor is present, preferably downstream of the NO_x catalytic converter.

The object of the present invention is to simplify the cleaning of the exhaust gas of an internal combustion engine in such a way that the separate lambda probe arranged downstream of the catalytic converter can be omitted.

This object is achieved through the features of primary Claims 1 and 5.

According to the present invention, a sensor which detects the NO_x concentration in exhaust gas is provided downstream of the three-way catalytic converter. There is a connection between the NO_x concentration and the lambda value which is used for correction of the signal level assigned to the value λo of the probe situated upstream of the catalytic converter. The invention is based on the recognition that the signal of the sensor close to the value assigned to λo at the NO_x concentration corresponding to lambda = 1 only has a local minimum if the sensor which detects the NO_x concentration has a cross sensitivity to NH_3. This, for example, is the case with known oxygen-conductive solid electrolytic sensors which have a measuring cell in which an oxygen concentration corresponding to lambda = 1 is set. Thus such a measurement of the connection does not permit an unambiguous assignment of an NO_x concentration to a lambda value, in particular no unambiguous assignment of the lambda value λo close to lambda = 1 to a value of the output signal of the sensor.

Therefore according to the invention use is also made of an internal signal of the sensor for trim regulation which demonstrates a sign change at lambda = 1. By means of the sign of this internal signal, the output signal which reflects the NO_x concentration can be definitely assigned to a lambda value since the range lambda < 1 can be distinguished from lambda >1 although the output signal of the sensor does not allow this differentiation since at lambda = 1 it only has a local minimum.

Thus trim regulation is possible without the use of a separate lambda probe arranged downstream of the catalytic converter, and it can be ensured that the

catalytic converter is operated in the range of optimal lambda values, i.e., at λo with a maximum conversion rate.

In contrast to the use of a separate lambda probe arranged downstream of the catalytic converter for trim regulation, as a result of the steepness of the NO_x concentration in the range lambda >1 and the steepness of the characteristic curve characterised by its NH_3 cross sensitivity in the range lambda < 1 combined with the full utilisation of the internal signal, an increased degree of precision of trim regulation is also obtained. In contrast to the non-prepublished German patent application DE 198 19 461.7 of the applicant having older priority, there is in addition the advantage that a drifting of the mixture of the internal combustion engine into the lean range and thus of the lambda value of the exhaust gas to values of lambda < 1 is more easily recognised. This is achieved in that the cross sensitivity of the sensor to NH_3 is fully utilised in the rich exhaust gas and the internal signal is used in addition to the output signal of the sensor which indicates the NO_x concentration.

A thick film sensor is advantageously used as NO_x sensor. Such a sensor is described in the publication of N. Kato et al., "Performance of Thick Film NO_x Sensor on Diesel and Gasoline Engines," Society of Automotive Engineers, Publication 970858, 1997. This sensor has two measuring cells and is composed of an oxygen-ion-conductive zirconium oxide. It embodies the following measuring concept: In a first measuring cell, to which the gas to be measured is brought across a diffusion barrier, a first oxygen concentration is set by means of a first oxygen ion pump stream, whereby no decomposition of NO_x takes place. In a second measuring cell which is connected to the first measuring cell via a diffusion barrier, the oxygen content is further lowered by means of a second oxygen ion pump stream and NO_x is decomposed at a

measuring electrode. The oxygen thus generated is detected as a measure of the NO_x concentration.

In such a sensor, the first oxygen ion pump stream can be configured as the internal signal.

The use of an NO_x sensor for the trim regulation is particularly advantageous if such a sensor is already present for the regulation of an NO_x catalytic converter.

Other, preferred, features and advantages are set forth in, and will become apparent from, the accompanying description and appended dependent claims.

At least one embodiment of the invention will now described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows a diagram with the relationship between lambda value and NO_x concentration in the exhaust gas of an internal combustion engine downstream of a three-way catalytic converter,

Figure 2 shows a block diagram of an internal combustion engine with an exhaust gas cleaning apparatus,

Figure 3 shows a diagram which shows the lambda value indicated for various bandwidth lambda probes as a function of the actual lambda value,

Figure 4 shows a schematic sectional representation of the sensor which detects NO_x concentration, and

Figure 5 shows a diagram similar to that of Figure 1 for the sensor of Figure 4 which has a cross sensitivity to NH_3.

Referring to Figure 2, an exhaust gas cleaning apparatus for cleaning the exhaust gas of an internal combustion engine is shown. The internal combustion engine can be either a carburetted or a fuel-injected internal combustion engine. The operation of the internal combustion engine 20 of Fig. 2 is controlled by an operating control device 25. A fuel feed system 21, which, for example, can be configured as a fuel injection apparatus, is triggered by the operating control device 25 via lines which are not more particularly designated and provides for the fuel apportionment of the internal combustion engine 20. In its exhaust gas tract 27 is a three-way catalytic converter 22, which also has an NO_x-reducing function, for the regulation of which an NO_x sensor 24 is provided. Separate catalytic converters can naturally also be used, for example, an NO_x storage catalytic converter and a three-way catalytic converter. Three-way catalytic converter 22 has an optimal effect at a lambda value λo. Depending on the catalytic converter, λo can be between 0.99 and 1.

For the operation of three-way catalytic converter 22, a broadband lambda probe 23 is provided upstream of it which sends its measured values to operating control device 25 via lines which are not more particularly designated. In addition, the measured values of additional sensors, in particular for rotational speed, load, catalytic converter temperature, etc., are also brought to operating control device 25. With the aid of these measured values, operating control device 25 controls the operation of internal combustion engine 20.

Internal combustion engine 20 operates in such mode that the mean value of the signal of lambda probe 23 which indicates the oxygen content in the untreated exhaust gas corresponds to a predetermined signal level. In a normal,

fully functioning lambda probe 23, this signal level corresponds to λo in the exhaust gas, i.e., the lambda value at which catalytic converter 22 has an optimal effect.

The lambda value in the exhaust gas of an internal combustion engine is linked to the NO_x concentration as long as no NO_x-storing activity takes place in the exhaust tract. This connection is depicted in Fig. 1. Here the lambda value is borne on the x-axis and the NO_x concentration on the y-axis. As can be seen, the NO_x concentration increases strongly with a leaning of the mixture (lambda > 1), and with a rich mixture (lambda < 1) it assumes uniformly low values. Because of the flat curve of NO_x concentration in the range of the catalytic converter window which is illustrated through the two vertical dashed lines in Fig. 1, an evaluation of the signal of sensor 24 which indicates the NO_x concentration is not possible or is possible only with very great difficulty for values lambda < 1. As a rule, only a one-sided regulation is capable of reliably preventing the drifting of the lambda value in the direction of a rich mixture (lambda < 1).

Most NO_x sensors, however, have a cross sensitivity to NH_3. This applies in particular to thick film solid electrolyte sensors with Nernst measuring cells. Such a sensor is used for sensor 24.

In Fig. 4, a section through this NO_x sensor is schematically depicted. It is used in the device depicted in Fig. 2 as sensor 24 for determining the NO_x concentration in exhaust gas 27 of internal combustion engine 20. Sensor 24 is composed of a solid electrolyte 2 which is surrounded by the exhaust gas to be measured and is heated with a heater 13. The exhaust gas diffuses through a diffusion barrier 3 into a first measuring cell 4. The oxygen content is measured in measuring cell 4 by means of a first Nernst voltage V0 between a

first electrode 5 and a reference electrode 11 exposed to ambient air. Reference electrode 11 is arranged in an air channel 12 into which ambient air is admitted through an opening 14. Both electrodes are conventional platinum electrodes. The measured value of first Nernst voltage V0 is used for setting a control voltage Vp0. Control voltage Vp0 drives a first oxygen ion pump stream Ip0 through solid electrolyte 2 between first electrode 5 and an exterior electrode 6. The regulating intervention of first Nernst voltage V0 on control voltage Vp0, depicted by a dashed line, results in first oxygen ion pump stream Ip0 being regulated such that a predetermined first oxygen concentration is present in first measuring cell 4.

First measuring cell 4 is connected to a second measuring cell 8 via an additional diffusion barrier 7. The gas present in measuring cell 4 diffuses through this diffusion barrier 7. The second oxygen concentration in second measuring cell 8 is in turn measured by means of a second Nernst voltage V1 between a second electrode 9, which also is a platinum electrode, and reference electrode 11 and is used for regulating a second oxygen ion pump stream Ip1. Second oxygen ion pump stream Ip1 from first measuring cell 4 passes from second electrode 9 through solid electrolyte 2 to external electrode 6. With the aid of second Nernst voltage V1, it is regulated such that a predetermined slight second oxygen concentration is present in second measuring cell 8. Upon application of voltage V2 between measuring electrode 10 and reference electrode 11, the NO_x, which has been not effected by the processes to this point in measuring cells 4 and 8, is now decomposed at measuring electrode 10, which is configured to be catalytically effective, and the released oxygen is pumped through solid electrolyte 2 in a third oxygen ion pump stream Ip2 toward reference electrode 11. With sufficiently low residual oxygen content at measuring electrode 10, this third oxygen ion pump

stream Ip2 is carried only by oxygen ions which originated from the decomposition of NO_x. Stream Ip2 is thus a measure of NO_x concentration in measuring cell 8 and thus in the exhaust gas to be measured and represents the output signal of sensor 24.

In this NO_x sensor 24, which is cross sensitive to NH_3, however, a conversion of NH_3 into NO_x takes place in first measuring cell 4 whereby O_2 from the measuring cell is consumed. Thus the first Nernst voltage V0 proves to be greater as a result of this reduction of oxygen content in first measuring cell 4 than would correspond to the oxygen content and thus the lambda value in the exhaust gas. Accordingly the value of pump stream Ip0 increases if HN_3 is present in the exhaust gas. Since NH_3 is present in the exhaust gas above all with a rich mixture, sensor 24 as a result of the cross sensitivity to NH_3 shows an output signal for lambda values < 1 which is elevated in comparison with that of a sensor which is not cross sensitive. The resulting characteristic is depicted in Fig. 5.

As can be seen, the curve of Fig. 5 at lambda = 1 is at a minimum. In the direction of a rich mixture, it increases as a result of the NH_3 cross sensitivity. In the direction of a lean mixture, it increases as a result of the abruptly increasing NO_x concentration in the lean mixture.

Since the oxygen concentration in first measuring cell 4 is measured through Nernst voltage V0 and is regulated by means of oxygen ion pump stream Ip0 or its control voltage Vp0 to a predetermined first oxygen concentration, which corresponds to lambda = 1 in the exhaust gas, the sign of Ip0 changes at lambda = 1 for the following reasons: If the exhaust gas has a lambda value < 1, control voltage Vp0 causes an oxygen ion pump stream Ip0 such that the first oxygen concentration in first measuring cell 4 corresponds to lambda = 1;

an oxygen ion pump stream thus flows from reference electrode 11 located in air channel 12 into first measuring cell 4 to first electrode 5. If, in contrast, the lambda value of the exhaust gas is greater than 1, control voltage Vp0 causes an oxygen ion pump stream Ip0 in the opposite direction, i.e. with a different sign. The sign of first oxygen ion pump stream Ip0 thus changes at lambda = 1.

Trim regulation is thus realised in the following manner: NO_x sensor 24 detects the NO_x concentration in the exhaust gas downstream of catalytic converter 22. The output signal as well as oxygen ion pump stream Ip0 is conducted to a trim regulator 26 which can be an independent device or can be provided in operating control device 25. In order to fine-tune the signal level of lambda probe 23 assigned to λo, which will be described below, and to compensate for changes in lambda probe 23, the mixture of the internal combustion engine is regulated to a special value of NO_x concentration. However, since the output signal of sensor 24 at lambda = 1 has only a local minimum, first oxygen ion pump stream Ip0 of sensor 24 must be increased in order to distinguish whether an output signal of NO_x sensor 24 must be assigned to the range lambda < 1 or the range lambda > 1. The sign of this internal signal unmistakably indicates this. The evaluation is facilitated or made possible as a result of the value of pump stream Ip0 being increased because of the NH_3 cross sensitivity in a rich mixture as a result of which the noise components of pump stream Ip0 can be neglected.

Trim regulator 26 then recognises a shift caused, for example, by ageing by means of the signal level of lambda probe assigned to λo of lambda probe 23 and compensates for it so that regulation of internal combustion engine 20 by operating control device is assured such that the average lambda value of the

untreated exhaust gas in exhaust tract 27 upstream of catalytic converter 22 corresponds on average to the desired value λo.

In Fig. 3 the effect of the trim regulation on the signal curve of broadband lambda probe 23 is depicted. The solid line 17 corresponds to an ideal probe in which the displayed lambda value always corresponds to the actual lambda value. The more finely dotted curve in Fig. 3 shows for example an aged lambda probe. This lambda probe indicates excessively high lambda values and in addition has reduced sensitivity. Through the trim regulation, curve 16 can be corrected so that the signal of aged lambda probe 23 corresponds to that of a probe with curve 15 which very closely approximates the ideal curve 17 in the area of λo or lambda = 1.

While according to the state of the art, a lambda probe downstream of catalytic converter 22 would be necessary in order to detect the lambda value in the treated exhaust gas behind catalytic converter 22 and thus to adjust the mixture so that the untreated exhaust gas if possible has the value λo, according to the invention this lambda probe can be omitted and in place of it NO_x sensor 24 can be used.

Claims

1. A method for cleaning the exhaust gas of an internal combustion engine with a catalytic converter having three-way properties arranged in the exhaust tract and a lambda probe arranged upstream of the catalytic converter in which

- regulation of the operation of the internal combustion engine is such that the lambda value of the untreated exhaust gas assumes predetermined values at the lambda probe, whereby a certain signal level of the lambda probe is assigned to lambda value λo which is close to lambda = 1;
- the concentration of an exhaust gas component is measured in a trim regulation downstream of the catalytic converter with three-way properties by an additional sensor; and
- depending thereon the signal level assigned to λo is corrected, wherein
- as an additional sensor, an NO_x sensor (24) is used which
  - detects the NO_x concentration in exhaust gas whereby a connection between NO_x concentration in exhaust gas and lambda value of the exhaust gas is present such that for lambda values > 1, the NO_x concentration in the exhaust gas and thus the output signal of the sensor increases sharply,
  - has a cross sensitivity to NH_3 so that for lambda values < 1, the output signal of sensor (24) likewise increases, and
  - has an internal signal which has a sign change at lambda = 1 and
- utilising the connection between NO_x concentration in the exhaust gas and the lambda value of the exhaust gas, a correction of the signal level

assigned to λo is effected with the aid of the output signal and of the internal signal of the sensor (24).

2. A method according to Claim 1, wherein the NO_x sensor (24) serves to regulate an NO_x reducing or storing catalytic converter (22) arranged in the exhaust tract.

3. A method according to Claim 1 or 2, wherein the mixture is regulated such that the output signal of the NO_x sensor (24) has a predetermined NO_x concentration corresponding to λo and the sign of the internal signal is evaluated in order to assign the output signal to a range corresponding to lambda < 1 and a range corresponding to lambda > 1.

4. A method according to one of the preceding claims, wherein the internal signal is a pump stream of an oxygen measuring cell of the sensor (24) with which the oxygen concentration in this measuring cell is set to a value corresponding to lambda = 1.

5. A device for the cleaning of the exhaust gas of an internal combustion engine (20) having:

- a catalytic converter (22) having three-way properties arranged in the exhaust tract (27),

- a lambda probe (23) arranged upstream of catalytic converter (22),

- an operating control device (25, 26) which controls the internal combustion engine (20) so that the exhaust gas assumes predetermined lambda values at the lambda probe (23), whereby a certain signal level of the lambda probe (23) is assigned to a lambda value λo which is close to lambda = 1; and

- an additional sensor (24) arranged downstream of the catalytic converter (22) which detects the concentration of an exhaust gas component, wherein

the additional sensor is an NO_x sensor (24) which

- detects the NO_x concentration in the exhaust gas whereby there is a connection between NO_x concentration in the exhaust gas and the lambda value of the exhaust gas so that for lambda values > 1, the NO_x concentration in the exhaust gas and thus the output signal of the sensor (24) increases sharply,

- has a cross sensitivity to NH_3 so that for lambda values < 1, the output signal of the sensor (24) rises in like manner,

- has an internal signal Ip0 which at lambda = 1 has a change of sign, and

- is connected with the operating control device (25, 26) so that the output signal and the internal signal Ip0) are conducted to it such that the operating control device (25, 26) utilising the connection between NO_x concentration in the exhaust gas and lambda value of the exhaust gas with the assistance of the output signal and of the internal signal (Ip0) makes a correction of the signal level assigned to λo of the sensor (24).

6. A device according to Claim 5, wherein the sensor (24) has: a first measuring cell (4) into which a portion of the exhaust gas is introduced and in which an oxygen concentration is regulated by means of an oxygen ion pump stream (Ip0), whereby the oxygen ion pump stream (Ip0) is the internal signal.

7. A device according to Claim 6, wherein the sensor (24) has a second measuring cell (8) which is connected to the first measuring cell (4) and in which a second oxygen concentration is adjusted whereby the NO_x

concentration is measured by a measuring electrode (10) in the second measuring cell (8).

8. A device according to one of the preceding device claims, wherein the operating control device (25, 26) has a sign-evaluating unit to which the internal signal (Ip0) is conducted and which indicates at the output whether the output signal which is to be assigned to a lambda value must be assigned with a range with lambda < 1 or a range with lambda > 1.

9. A device or method according to one of the preceding claims, wherein λo is a lambda value between 0.99 and 1.

10. A method of cleaning the exhaust gas of an internal combustion engine substantially as hereinbefore described with reference to the accompanying drawings.

11. A device for cleaning the exhaust gas of an internal combustion engine substantially as hereinbefore described with the reference to the accompanying drawings.

16

Application No: GB 9926642.1
Claims searched: 1-11

Examiner: Dave Mobbs
Date of search: 15 February 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): G1N NBKT, NBMH; G3R RBE72.

Int Cl (Ed.7): F02D 41/14; G01N 27/417.

Other: ONLINE: EPODOC, JAPIO, WPI, English language full-text databases.

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	EP 0,814,249 A (NGK INSULATORS, LTD.)	

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Attorney Docket No. R 36559
Application Serial No. 09/737,603

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.